ADBI Working Paper Series

Macroeconomic Effects of Oil Price Fluctuations on Emerging and Developed Economies in a Model Incorporating Monetary Variables

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No. 546
October 2015

Asian Development Bank Institute

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Suggested citation:

Taghizadeh-Hesary, F., and N. Yoshino. 2015. Macroeconomic Effects of Oil Price Fluctuations on Emerging and Developed Economies in a Model Incorporating Monetary Variables. ADBI Working Paper 546. Tokyo: Asian Development Bank Institute. Available: http://www.adb.org/publications/macroeconomic-effects-oil-price-fluctuations-emerging-and-developed-economies-model/

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Abstract

The goal of this paper is to examine the impact of crude oil price movements on two macro variables, the gross domestic product (GDP) growth rate and the consumer price index (CPI) inflation rate, in three countries, the People's Republic of China (an emerging economy), Japan, and the United States (developed economies), in a model incorporating monetary variables (money supply and exchange rate). The main objective of this research is to investigate whether these economies are still reactive to oil price movements and compare their reactions. Monetary variables are included in this survey because our earlier research showed that they have a significant role in oil price determination. To assess the relationship between crude oil prices and macro variables we adopt an N-variable structural vector autoregression (SVAR) model. The results suggest that the impact of oil price fluctuations on developed oil importers' GDP growth is much milder than on the GDP growth of an emerging economy. On the other hand, however, the impact of oil price fluctuations on the People's Republic of China's inflation rate was found to be milder than in the two developed countries that were examined.

JEL Classification: Q43, E31, O57

Contents

1. INTRODUCTION AND LITERATURE REVIEW

More than 40 years have passed since the first oil price shock of 1973. During this period, global demand for oil has risen drastically, while at the same time, new energy-related technologies and new energy resources have made global consumers more resistant to oil shocks. Since the oil shocks of the 1970s, emerging economies have come to play a much larger role in global energy consumption. The People's Republic of China's (PRC) share, for example, is 5 times larger than it was in the 1970s. On the other hand, the shares of the two largest developed oil consumers, the US and Japan, decreased from about 32% and 10% to 21% and 5%, respectively.

Following the oil crises of the 1970s and the economic recessions that followed, several studies have found that oil price shocks played a significant role in economic downturns. In recent years, both the sharp increase in oil prices that began in 2001 and the sharp decline that followed in 2008 following the subprime mortgage crisis have renewed interest in the effects of oil prices on the Macroeconomy. Following the financial crisis of 2007–2008, crude oil prices dropped from $133.11 in July 2008 to below $42.01 in December 2008, due to decreased global demand. Shortly after this drop, however, they started to rise sharply again.

In this research we will assess and compare the impact of oil price fluctuations on the following macroeconomic factors: the gross domestic product (GDP) growth rate and consumer price index (CPI) inflation. We look at these factors in the three largest crude oil consumers: the United States (US) and Japan (developed economies), and the PRC (an emerging economy). We will answer the question of whether these economies are still elastic to oil price movements, or whether new, energy-related technologies and resources, like renewables and shale gas, have completely sheltered them from shocks. If they are still elastic, are emerging and developed economies influenced to the same degree?

Reviewing the literature of oil prices since 1970s until now, several studies have assessed the impacts of oil prices on various economic variables.

Blanchard and Gali (2007) characterized the macroeconomic performance of a set of industrialized economies in the aftermath of the oil price shocks of the 1970s and of the last decade, using a six-variable vector autoregression (VAR) model. They found a significant role of oil prices in the economic downturns. The variables used in their survey were the nominal price of oil (in US dollars), three inflation measures (CPI, GDP deflator, and wages) and two quantities (GDP and employment). Kilian (2008a) addressed a numbers of issues, including how energy price shocks affect US real output, inflation, and stock prices. The variables used were the nominal oil price, real oil price, and GDP. The study found that it is critical to account for the endogeneity of energy prices and to differentiate between the effects of demand and supply shocks in energy markets. Levent and Acar (2011) analyzed the economic effects of oil price shocks for Turkey as a small, open oil- and gas-importing country. They analyzed the potential long-term effects of oil price shocks on macroeconomic variables of interest—including GDP, consumer price inflation, indirect tax revenue, the trade balance, and carbon emissions—using a dynamic, multi-sectoral general equilibrium model for the Turkish economy. Their simulation results showed that oil prices have significant effects on macro indicators. In a more recent study, Taghizadeh-Hesary et al. (2013) evaluated the impact of oil price shocks on oil producing and consuming economies; the study used a simultaneous equation framework for different countries with business relations. As expected, the results showed that oil producers (Iran and the Russian Federation) benefit from oil price shocks. For oil-consuming economies, the effects are more diverse. In some countries, output falls in response to an oil price shock, while others seem to be relatively immune. Variables used in the survey were GDP, trade share, and oil prices.

However, the advantage of our survey compared with the aforementioned papers and other research that has been done in the field of oil prices is that we include monetary variables (money supply and exchange rate). Monetary policy has a significant impact on inflating the price of oil and other commodities (see, inter alia, Taghizadeh-Hesary and Yoshino [2014, 2015] and Yoshino and Taghizadeh-Hesary [2014a]). On the other hand, monetary policy has a crucial role in general price determination and on economic growth movement (e.g., Sims [1980, 1992]; Romer and Romer [1989]; Yoshino et al. [2014]; and Yoshino and Taghizadeh-Hesary [2015]). Bernanke, Gertler, and Watson (1997) argue that much of the decline in output and employment in the US was due to the rise in interest rates. Hence, due to the above reasons it is essential to include monetary variables (money supply and the exchange rate) in our survey.

Our analysis shows that the impact of oil price movements on developed oil importers' GDP growth is much milder than on the GDP growth of an emerging economy. On the other hand, the impact of oil price fluctuations on the PRC's inflation rate was found to be milder than in the two developed countries.

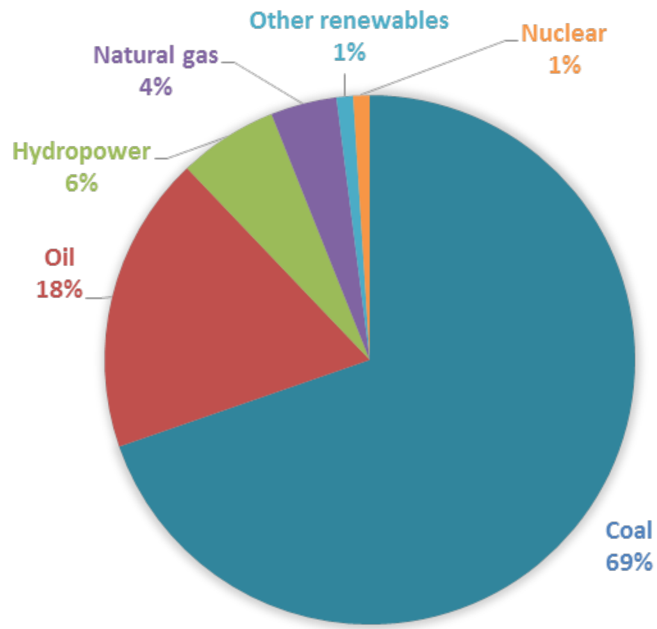
This paper is structured as follows. In the next section, we present an overview of oil and energy in the PRC, Japan, and the US. In the third section we provide theoretical framework including: the relationship between energy prices and economic growth, the relationship between energy prices and general price levels, and the impact of higher energy prices on supply and demand in the economy. Our model is explained in the fourth section, and in the fifth section we describe our empirical analysis. The sixth section concludes the paper.

2. OVERVIEW OF OIL AND ENERGY IN THE PRC, JAPAN, AND THE US

2.1 People's Republic of China

The PRC has quickly risen to the top ranks in global energy demand over the past few years. It is the world's second largest oil consumer behind the US and became the largest global energy consumer in 2010. The economy was a net oil exporter until the early 1990s and became the world's second-largest net importer of crude oil and petroleum products in 2009. The PRC's oil consumption growth accounted for one-third of the world's oil consumption growth in 2013 (EIA 2014a). Natural gas use in the PRC has also increased rapidly in recent years, and the country has sought to raise natural gas imports via pipelines and the use of liquefied natural gas (LNG). The PRC is the world's top coal producer, consumer, and importer, and accounts for about half of global coal consumption—an important factor in world energy-related carbon dioxide emissions. The PRC's rising coal production is the key driver behind the economy becoming the world's largest energy producer in 2007. Coal supplied the vast majority (69%) of the PRC's total energy consumption in 2011. Oil was the second-largest source, accounting for 18% of total energy consumption. While the PRC has made efforts to diversify its energy supplies, hydropower sources (6%), natural gas (4%), nuclear power (nearly 1%), and other renewables (1%) account for small shares of energy consumption (Figure 1).

Figure 1: Total Energy Consumption in the PRC by Type, 2011



Note: Percentages may not total 100% because of rounding.

Source: Energy Information Administration. International Energy Statistics. Washington, DC: United States Energy Information Administration.

According to a project carried out by the Institute of Energy Economics of Japan (IEEJ 2013), the PRC's oil consumption will almost double over the next 30 years, reaching 866 million tons of oil equivalent[1] (Mtoe) by 2040. During this period, the PRC will replace the US as the world's largest oil consumer. Driving the increase will be the transportation sector, including road transportation. With the potential to expand the vehicle market from its current 7% vehicle ownership rate, the number of vehicles in the PRC is expected to increase to 360 million in 2040, meaning that the transportation sector will double its oil consumption. The country's share of global gasoline consumption is also expected to expand from its current 8% to 18%, exceeding its share of the global population. This projection continues by saying that by 2040 the PRC will have the world's largest nuclear power generation capacity, and will account for half of the increase in global nuclear generation capacity between 2011 and 2040. Renewable energy will account for 9.7% of the country's primary energy consumption in 2040 (Taghizadeh-Hesary, Yoshino, and Assari-Arani 2015).

2.1.1 Oil Consumption in the PRC

As of January 2014, the PRC held 24.4 billion barrels of proven oil reserves, up by over 0.7 billion barrels from the 2013 level and the highest in the Asia and the Pacific region. The PRC's total oil and liquids production, the fourth largest in the world, has risen by about 54% over the past 2 decades and serves only its domestic market (EIA 2014a). However, production growth has not kept pace with demand growth during this period. In 2013, the country produced an estimated 4.5 million barrels per day (bbl/d) of total oil liquids, of which 93% was crude oil. The EIA forecasts oil production to rise to about 4.6 million bbl/d by the end of 2014. Over the longer term, the EIA projects a steady growth for the PRC's oil and liquids production, to 4.6 million

[1] Equal to about 6,186 million barrels of oil equivalent.

bbl/d in 2020 and 5.6 million bbl/d by 2040. Most of the growth over the long term is from non-petroleum liquids such as gas-to-liquids, coal-to-liquids, kerogen, and biofuels, as crude oil production remains relatively flat. Oil consumption growth has eased after a high of 14% in 2009, reflecting the effects of the recent global financial and economic downturn. Despite the slower growth, the country still made up nearly a third of global oil demand growth in 2013, according to EIA estimates, with an estimated consumption of 10.7 million bbl/d of oil in 2013, up 380 thousand bbl/d, or almost 4%, from 2012. In 2009, the PRC became the second largest net oil importer in the world behind the US, and average net total oil imports reached 6.2 million bbl/d in 2013. Notably, for Q4 2013, the PRC actually became the largest global net importer of oil. The country's oil demand growth hinges on several factors, such as domestic economic growth and trade, power generation, transportation sector shifts, and refining capabilities. The EIA forecasts that oil consumption will continue growing through 2014 at a moderate pace to approximately 11.1 million bbl/d, and net oil imports will reach 6.6 million bbl/d compared to 5.5 million bbl/d for the US (EIA 2014a).

2.2 Japan

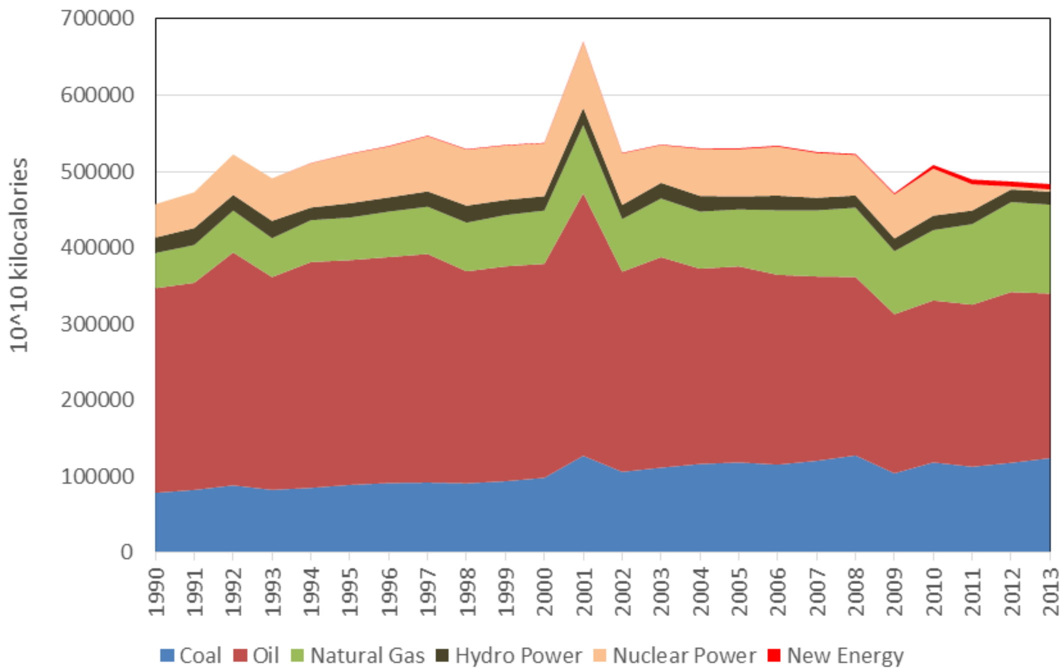
Japan is the world's largest liquefied natural gas (LNG) importer, the second largest coal importer, and third largest net oil importer behind the US and the PRC. Japan has limited domestic energy resources, which meet less than 15% of the country's own total primary energy use.

2.2.1 Total Primary Energy Consumption in Japan

In March 2011, a 9.0 magnitude earthquake struck off the coast of Sendai, Japan, triggering a large tsunami. The damage to Japan resulted in an immediate shutdown of about 10 gigawatts (GW) of nuclear power generating capacity. Between the 2011 Fukushima nuclear power plant disaster and May 2012, Japan lost all its nuclear capacity as a result of scheduled maintenance and lack of government approvals to return to operation. Japan replaced the significant loss of nuclear power with generation from imported natural gas, low-sulfur crude oil, fuel oil, and coal (Yoshino and Taghizadeh-Hesary 2014a). Oil remains the largest source of primary energy in Japan. Coal continues to account for a significant share of total energy consumption, although natural gas is increasingly important as a fuel source and is currently the preferred fuel of choice to replace the nuclear shortfall. The total primary consumption of natural gas rose from 19% in 2010 to 24% in 2012. Before the 2011 earthquake, Japan was the third largest consumer of nuclear power in the world, after the US and France, and nuclear power accounted for about 13% of the country's total energy in 2010. In 2012, the nuclear energy share fell to 1% of total energy consumption (and contributed a similar level to primary energy consumption in 2013 as only two reactors were operating for a little more than half of the year), and in 2014 Japan did not produce any nuclear power. Hydropower and other renewable energy comprise a small percentage of total energy consumption in Japan (EIA 2014b).

Figure 2 shows primary energy consumption in Japan by type based on thermal values from 1990 to 2013.

Figure 2: Primary Energy Consumption in Japan by Type Based on Thermal Values, 1990–2013



Notes: Annual data were obtained by summing up the monthly data in each year.

Thermal values are based on General Energy Statistics (Agency of Resources and Energy).

Hydropower data before 1999 include geothermal power.

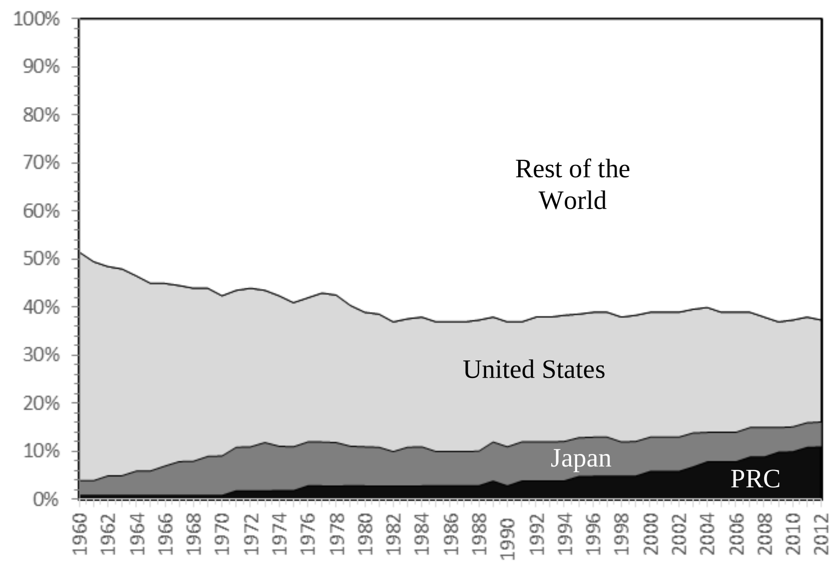
The data include estimated values.

Sources: Ministry of Economy, Trade and Industry of Japan. Monthly Statistics of Electric Power, Coal Statistics Report, Oil Statistics Report. Monthly Statistics of Demand and Supply of Energy, Trade Statistics.

2.2.2 Oil Consumption in Japan

Figure 3 shows the shares of the world's three major oil consumers: the US, Japan, and the PRC. As the figure shows, the US and Japan's shares are decreasing while the shares of the PRC and the rest of the world are on the rise.

Figure 3: Share of the Three Major Oil Consumers in Global Oil Consumption, 1960–2012



PRC = People's Republic of China.

Source: Organization of the Petroleum Exporting Countries (2013). *Annual Statistical Bulletin*. Vienna: Organization of the Petroleum Exporting Countries.

Japan consumed nearly 4.6 million bbl/d in 2013, down from 4.7 million bbl/d in 2012, making it the third largest petroleum consumer in the world, behind the US and the PRC. However, oil demand in Japan has declined overall since 2000 by nearly 15%. This decline stems from structural factors, such as fuel substitution, a declining population, and government-mandated energy efficiency targets. In addition to the shift to natural gas in the industrial sector, fuel substitution is occurring in the residential sector as high prices have decreased demand for kerosene in home heating. Japan consumes most of its oil in the transportation and industrial sectors, and is also highly dependent on naphtha and low-sulfur fuel oil imports. Demand for naphtha has fallen as ethylene production is gradually being displaced by petrochemical production in other Asian economies. Demand for low-sulfur fuel oil and direct use of crude oil rose substantially in 2012 as these fuels replaced some nuclear power generation and supported the post-disaster reconstruction works. Japan's oil consumption rose by 255,000 bbl/d in 2012 from the 2011 level. Oil consumption began declining in 2013 as Japan relied more on natural gas and coal to substitute for the lost nuclear generation. The EIA assumes that net total oil consumption will continue declining in 2015 as nuclear capacity comes back online (EIA 2014b).

In the wake of the Fukushima nuclear incident the price of electricity was raised for the government, utilities, and consumers. Increases in the cost of fuel imports have resulted in Japan's top 10 utilities losing over $30 billion in the past 2 years. Japan spent $250 billion on total fuel imports in 2012, a third of its total import charge. Despite strength in export markets, the yen's depreciation and soaring natural gas and oil import costs from a greater reliance on fossil fuels continued to deepen Japan's recent trade deficit throughout 2013.

Oil remains the largest source of primary energy in Japan, although its share of total energy consumption declined from about 80 % in the 1970s to 43 % in 2011. Japan consumed over 4.7 million barrels of oil per day in 2012.

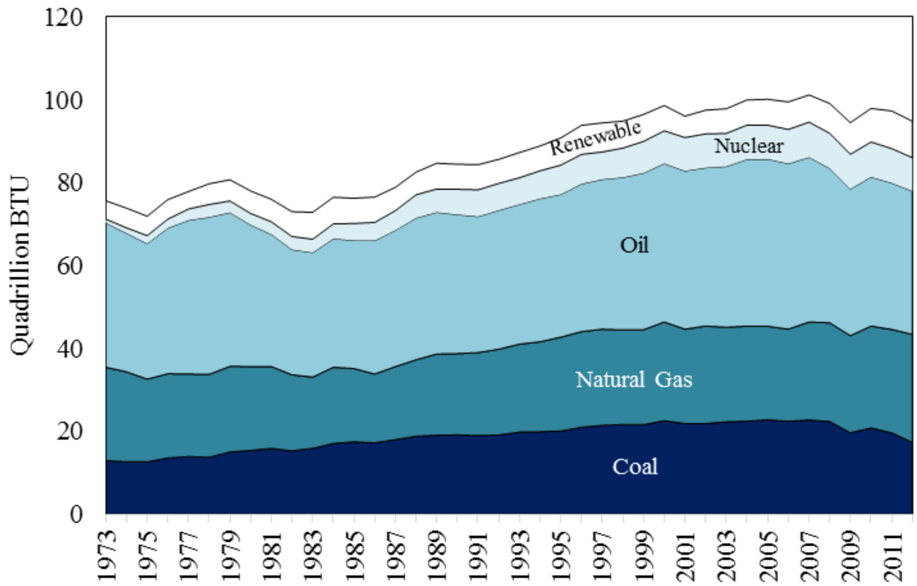
2.3 United States

2.3.1 Total Primary Energy Consumption in the US

In 2012, the US consumed over 94 quadrillion British thermal units (BTU) of primary energy, making it the world's second largest energy consumer after the PRC (Taghizadeh-Hesary et al. 2015).

Figure 4 shows US primary energy consumption by source. The share of crude oil decreased from 46% in 1973 to 36% in 2012, while the shares of natural gas (driven especially by the shale gas revolution), nuclear power, and renewable energy have risen drastically.

Figure 4: United States Primary Energy Consumption by Source, 1973–2011



BTU = British thermal unit.

Note: Natural gas consumption excludes supplemental gaseous fuels.

Source: EIA (2014c).

As for oil consumption, the US still ranks highly among global oil consumers, with consumption at about 18.49 million bbl/d (EIA 2014c). Although oil consumption decreased from its peak in 2005, it is still the main energy source in the US. Today, oil meets 36% of US energy demand, with 70% directed to fuels used in transportation—gasoline, diesel, and jet fuel. Another 24 % is used in industry and manufacturing, 5% is used in the commercial and residential sectors, and less than 1% is used to generate electricity. Oil is the main mover of US national commerce and its use in transportation has allowed people to become more easily connected. Almost all US transportation is dependent upon fuel in concentrated liquid form. The major sources of US imported oil are Canada, Mexico, and Organization of the Petroleum Exporting Countries (OPEC), particularly Saudi Arabia, including 20% coming from the Persian Gulf. In 2014, the US proved is reserves of crude oil and lease condensate and exceeded 36 billion barrels.

3. THEORETICAL FRAMEWORK

3.1 Relationship between Energy Prices and Economic Growth

On the supply side of the economy, in addition to elements of labor and capital, energy is also considered to be a substantial element of production. Therefore, production can be shown as a function of labor, capital, and energy. Hence:

$$Q_t = (L_t(\tfrac{W_t}{P_{Qt}}, Q_t), K_t(i_t, Q_t), E_t(\tfrac{P_{Et}}{P_{Qt}}, Q_t)) \tag{1}$$

where Q_t stands for gross output, L_t is labor input, K_t is capital input, E_t is energy (oil, gas, and coal) input, W_t denotes the nominal wage rate, i_t is the nominal interest rate, and P_{Et} and P_{Qt} are the energy price,[2] and consumer price index (CPI), respectively. Eq. (1) shows that the three elements of labor, capital, and energy lead to the alteration of levels of production. Furthermore, there are direct relationships between the use of such elements and the level of production. In other words, a rise of each of the elements leads to an increase in production:

$$\frac{\partial Q_t}{\partial L_t} > 0, \frac{\partial Q_t}{\partial K_t} > 0, \frac{\partial Q_t}{\partial E_t} > 0 \tag{2}$$

In addition, the consumption of each of the energy resources, oil, gas, and coal, is a reverse function of their price levels:

$$\frac{\partial E_t}{\partial P_{Et}} < 0 \quad \text{and} \quad \frac{\partial E_{Ot}}{\partial P_{Ot}} < 0, \frac{\partial E_{Gt}}{\partial P_{Gt}} < 0, \frac{\partial E_{Ct}}{\partial P_{Ct}} < 0 \tag{3}$$

where, E_{Ot}, E_{Gt}, E_{Ct} stands for oil, gas, and coal consumption, respectively. P_{Ot} denotes the oil price, P_{Gt} the gas price, and P_{Ct} the coal price. Therefore, if the general index of energy prices is increased, its consumption decreases. However, if only the price of one source (given oil) increases among other the sources of energy, or if its price increase is higher than other sources, then the increase in price of that source will partly be offset by a substitution of other sources. The rates of such substitution will depend on the technical ability of other sources to replace it and on the period of time available for such an adjustment. Therefore, an increase in oil price shall lead to the substitution of oil by other sources of energy. Furthermore, as it is a production factor, it will have short-term effects on the increase of production costs and will lead to the reduction of real production of oil importer countries. In the long run too, it leads to a rise in costs; the rate of which will depend on the ability of other sources to replace oil. If the ability to substitute exists, such price increases will have no important effect on costs. Usually, most researchers consider the relationship between “energy” and “labor and capital” to be a substitution under normal conditions. However, they consider the cross elasticity between them to be negative in the short run. In other words, “energy” and “labor and capital” will be supplements of each other in the short run because the structure of industries is such that they may not react against a rise in costs (Bohi 1991). Hence, we may conclude that the short-term effect of an energy price shock will be bigger than its long-term one. This is reasonable because when there is a rise in energy prices, in the long run industries change the structure of their production as much as possible to use fewer costly resources. In industries where energy is

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[2] Weighted average of crude oil, natural gas and coal prices.

used as an intermediary resource of production, a rise in energy prices drastically affects the potential production output, thereby affecting GDP. If we consider that "energy" and "labor and capital" are substitutable, the rise in energy prices leads to an increase in the use of the two parameters of capital and labor, which makes the allocation costs of parameters and relative shares for the two parameters of labor and capital rise (Taghizadeh-Hesary et al. 2013).

This section showed that higher energy prices as one of the production inputs, reduces the output level. On the other hand, following higher energy prices, household consumption and the demand side of the economy also suffer and result in a lower GDP level (see Section 3.3 of this paper).

3.2 Relationship between Energy Prices and the General Price Level

In order to show the relationship between energy prices and the general price level, we adopt a three-input Cobb-Douglas production function:

$$Q_t = \mathrm{T} L_t^{\alpha}{}_{(\frac{W_t}{P_{Qt}}, Q_t)} K_t^{\beta}{}_{(i_t(M_t), Q_t)} E_t^{\gamma}{}_{(\frac{P_{Et}}{P_{Qt}}, Q_t)} \tag{4}$$

and assuming:

$$L_t = L_1 \frac{P_{Qt} Q_t}{W_t} \tag{5}$$

$$K_t = K_1 \frac{Q_t}{i_t(M_t)} \tag{6}$$

$$E_t = E_1 \frac{P_{Qt} Q_t}{P_{Et}} \tag{7}$$

where α, β, γ are the output elasticities of labor, capital, and energy, respectively, and assuming their summation is equal to one, meaning constant returns to scale. These values are constants determined by the available technology and T is the total factor productivity, which is assumed to be constant. M_t is the money supply, which determines the interest rate level. By substituting Eqs. (5)–(7) in Eq. (4) and log linearizing the result, then obtaining the first derivative with respect to time and writing the result for CPI, we obtain the below equation for the growth rates:

$$\frac{\partial LnP_{Qt}}{\partial t} = \delta \frac{LnW_t}{\partial t} + \chi \frac{Lni_t(M_t)}{\partial t} + \eta \frac{LnP_{Et}}{\partial t}; \delta = \frac{\alpha}{\alpha+\gamma}, \chi = \frac{\beta}{\alpha+\gamma}, \eta = \frac{\gamma}{\alpha+\gamma} \tag{8}$$

or,

$$\dot{P}_{Qt} = \delta \dot{W}_t + \chi \dot{i}_t(M_t) + \eta \dot{P}_{Et} \tag{9}$$

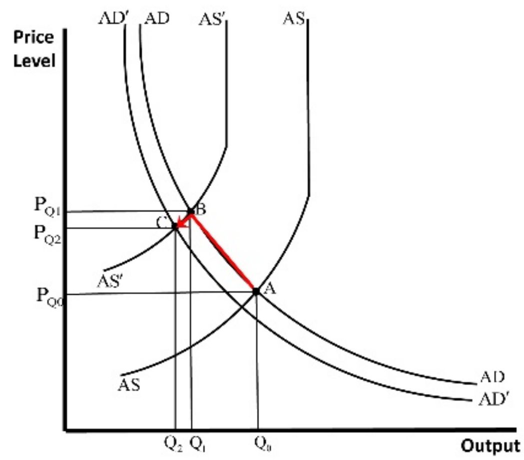
Eq. 9 depicts the relationship between production input prices which are: wage rate, interest rate and energy price growth rate and the CPI inflation rate in the supply side of the economy. Higher energy prices, higher wages, and higher money amount which ease the interest rate will push up general price level.

Higher energy prices affect not only the supply side of the economy but also household consumption on the demand side of the economy suffers as well. A more detailed description of the reactions of both the supply and demand sides of the economy to higher energy prices are graphically demonstrated in the following section.

3.3 Impact of Higher Energy Prices on the Supply and Demand Side of the Economy

A simple aggregate supply and demand model will clarify the analysis in this section.

Figure 5: Impact of Higher Energy Prices on Output and Price Level



Source: Authors' compilation.

In Figure 5, the economy is initially in equilibrium at point A with price level P_{Q0} and real output level Q_0. AD is the aggregate demand curve and AS stands for the aggregate supply curve. Aggregate supply curve has an upward sloping curve, which shows that at some real output level it becomes difficult to increase real output despite increases in the general level of prices. At this output level, the economy achieves full employment.

Suppose that the initial equilibrium, point A is below the full employment level. When the relative price of energy resources (crude oil, natural gas, coal, etc.) increases, the aggregate supply curve shifts to AS'. The employment of existing labor and capital with a given nominal wage rate requires a higher general price for output, if sufficient amounts of the higher-cost energy resources are to be used.

The productivity of existing capital and labor resources is reduced so that potential real output declines to Q_1. In addition, the same rate of labor employment occurs only if real wages decline sufficiently to match the decline in productivity. This, in turn, happens only if the general level of prices, P_{Q1}, rises sufficiently given the nominal wage rate. This moves the economy to the level of output Q_1 and price level P_{Q1}. This point is indicated in Figure 5 at point B, which is a disequilibrium point. Given the same supply of labor services and existing plants and equipment, the output associated with full employment declines as producers reduce their use of relatively more expensive energy resources and as plants and equipment become economically obsolete.

On the other hand, on the demand side of the economy, when the prices of energy resources rise, their consumption declines. Because of this drop in consumption, the aggregate demand curve shifts to AD', which in turn decreases prices from their previous disequilibrium level at P_{Q1} and sets them tat P_{Q2} as the final equilibrium price. This lowers the output levels due to reduced consumption in the economy, from the previous point of Q_1 to Q_2. This point is indicated in Figure 5 at point C, which is the final equilibrium point.

The economy may not adjust instantaneously to point C, even if point C is the new equilibrium. For example, price rigidities due to slow-moving information or other transactions costs can keep nominal prices from adjusting quickly (Tatom 1981). Consequently, output and prices move along an adjustment path such as that indicated by the arrow in Figure 5.

In this case, aggregate supply is the main chain of transmission of energy price shocks compared to aggregate demand. This means that the supply side of the economy is more affected by oil price shocks than the demand side of the economy, resulting in higher prices and lower output levels at the final equilibrium point, C, when compared to the initial equilibrium point A. If the demand side of the economy were the main transmission channel, the result would be a decrease in output and lower price levels compared to the initial equilibrium point.

4. MODEL

The main objective of this research is to assess and compare the impact of the price movements of crude oil, the main energy resource, on GDP growth rates and CPI inflation rates of an emerging and two developed economies in a model incorporating monetary variables. In developing this model we used Taghizadeh-Hesary and Yoshino (2013a) as a reference. In their model, they assumed that oil price movements transfer to macro variables through either supply (the aggregate supply curve) or demand channels (the aggregate demand curve). In order to examine the effects of this transfer, they used an IS curve to look at the demand side and a Phillips curve to analyze inflationary effects from the supply side.

Using this aforementioned research as inspiration, we chose to use the following variables in our survey: crude oil prices, natural gas prices, GDP, consumer price index (CPI), money supply, and the exchange rate. We included the natural gas price because it is the main substitute energy source for crude oil. GDP and CPI are included in our variables mainly because their movements have an impact on the crude oil market (Taghizadeh-Hesary and Yoshino 2013b, 2014), and also because our objective is to assess the impact of oil price fluctuations on these two macro variables.

The money supply and the exchange rate are monetary policy variables that have an impact on the crude oil market and on the whole economy. Hence, it is necessary to include each country's money supply and the exchange rate in our analysis (Barsky and Kilian 2002; Leduc and Sill 2004; Hamilton and Herrera 2004; Taghizadeh-Hesary and Yoshino 2014, 2015; Yoshino and Taghizadeh 2014a).

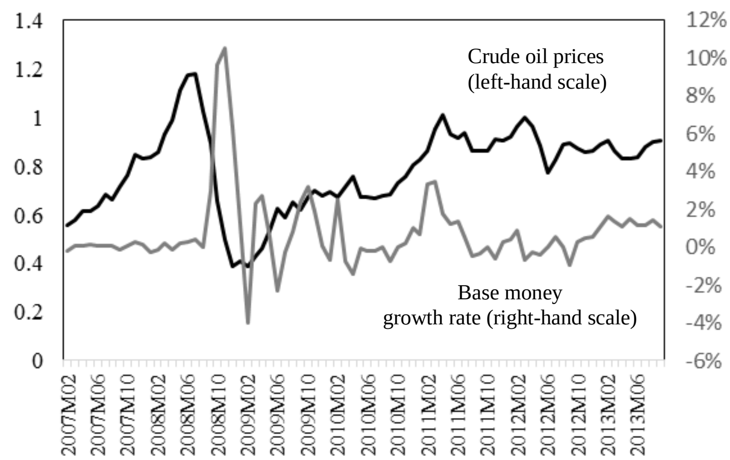
Taghizadeh-Hesary and Yoshino (2014) explain that oil prices accelerated from about $35/barrel in 1981 to beyond $111/barrel in 2011. At the same time, interest rates (the federal funds rate) subsided from 16.7% per annum to about 0.1%. By running a simultaneous equations model, they found that during the period 1980–2011, global oil demand was significantly influenced by monetary policy and supply actually remained constant. Aggressive monetary policy stimulates oil demand, while supply is inelastic. The result is skyrocketing crude oil prices, which inhibit economic growth.[3]

[3] Taghizadeh and Yoshino (2014), in order to define the determinants of crude oil prices, used two substitution sources for crude oil prices (natural gas prices and coal prices), two monetary policy factors (the exchange rate and interest rate) and GDP growth rate, which shows economic activity growth. In this present paper since we use an SVAR model, in order to avoid identification problems, we must use the minimum possible number of variables.

Yoshino and Taghizadeh-Hesary (2014) examined how monetary policy affected crude oil prices after the subprime mortgage crisis. They found that after the subprime mortgage crisis, the weaker exchange rate of the US dollar caused by the country's quantitative easing pushed oil prices in US dollars upward over the period 2009–2012 by causing investors to invest in the oil market and other commodity markets while the world economy was in recession in this period. This trend had the effect of imposing a longer recovery time on the global economy, as oil has been shown to be one of the most important production inputs.

Figure 6 depicts two monetary policy factors: base money and real effective exchange rate movements along with crude oil price movements. It illustrates the base money growth rate trend and the crude oil price movements during the period February 2007–September 2013. As is clear, in most cases they tend to follow the same path.

Figure 6: Base Money and Crude Oil Price, February 2007–September 2013



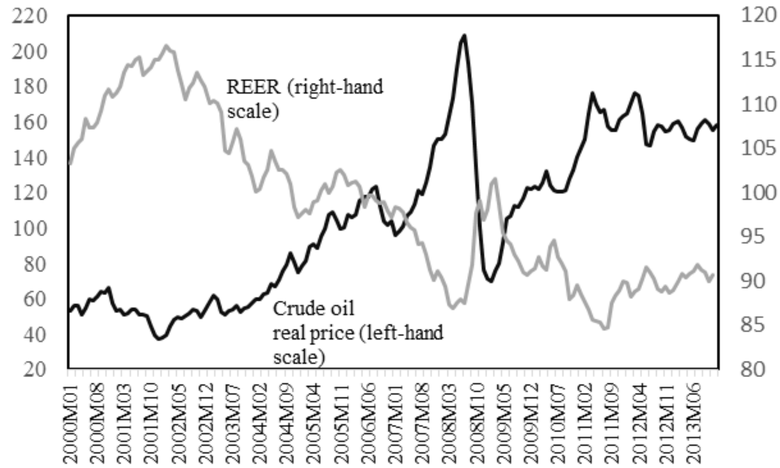
Notes: Crude oil prices are in constant dollars obtained using a simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market, deflated by the US consumer price index (CPI). The base money growth rate is for the US, seasonally adjusted. The left-hand scale is for crude oil real prices and the right-hand scale is for the base money growth rate.

Source: Yoshino and Taghizadeh-Hesary (2014a).

Figure 7 shows the real effective exchange rate (REER) and real crude oil price movements during the period January 2000–December 2013. The inverse relationship between these two variables is apparent in this figure. In most cases, crude oil prices began to rise following a depreciation of the US dollar, and dropped following an appreciation.

As such, for substitution sources of crude oil, we limited our selection to natural gas, which is the main substitute fuel, and eliminated coal throughout our study. As for monetary variables we used the money supply and the exchange rates. Moreover we added CPI, since this is one of the variables on which we expect to measure oil price movement impacts.

Figure 7: Exchange Rate and Crude Oil Prices, January 2000–December 2013



REER = real effective exchange rate.

Notes: crude oil prices are in constant dollars obtained using the simple average of: Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market, deflated by the US consumer price index (CPI). The real effective exchange rate (REER) is for US dollars. The right-hand scale is for REER and the left-hand scale is for real crude oil prices.

Sources: International Energy Agency (IEA) (2013); International Financial Statistics (IFS) (2013); and the Energy Data and Modelling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ).

To assess the relationship between crude oil prices, natural gas prices, GDP, the consumer price index (CPI), money supply, and the exchange rate variables, we adopt the N-variable Structural Vector Autoregression (SVAR) model and start with following VAR model:[4]

$$Y_t = A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + u_t \tag{10}$$

where Y_t is a $(N \times 1)$ vector of variables. $A_{i\,(i\,=\,1,\ldots,\,p)}$ are $(N \times N)$ fixed coefficient matrices, p is the order of the VAR model, and u_t is a $(N \times 1)$ vector of VAR observed residuals with zero mean and covariance matrix $E(u_t u_t') = \sum_u$. The innovations of the reduced form model, u_t, can be expressed as a linear combination of the structural shock, ε_t, as in Breitung, Bruggemann, and Lutkepohl (2004):

$$u_t = A^{-1} B \varepsilon_t \tag{11}$$

where, B is a structural form parameter matrix. Substituting Eq. (10) into Eq. (11) and following minor operations, we get the following equation, which is the structural representation of our model:

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[4] The SVAR approach has been developed over the last decade to interpret business cycle fluctuations and to help identify the effects of different economic policies. It is an extension on the traditional theoretical VAR approach in that it combines economic theory with time-series analysis to determine the dynamic response of economic variables to various disturbances. The main advantage of SVAR analysis is that the necessary restrictions on the estimated reduced form model, required for identification of the underlying structural model, can be provided by economic theory. These restrictions can be either contemporaneous or long-run in nature depending on whether the underlying disturbances are considered to be temporary or permanent in nature. Once the identification is achieved it is possible to recover the structural shocks (Gottschalk 2001).

$$AY_t = A_1^* Y_{t-1} + \ldots + A_p^* Y_{t-p} + B\varepsilon_t \tag{12}$$

where $A^*_{j(j=1,\ldots,p)}$ is a $(N \times N)$ matrix of coefficients; $A_j = A^{-1} A^*_{j(j=1,\ldots,p)}$ and ε_t are a $(N \times 1)$ vector of unobserved structural shocks, with $\varepsilon_t \sim (0, I_k)$. The structural innovation is orthonormal; the structural covariance matrix, $\sum_{\varepsilon} = E(\varepsilon_t \varepsilon_t{}')$, I_N is the identifying matrix. This model is known as the AB model, and is estimated in the form below:

$$Au_t = B\varepsilon_t \tag{13}$$

The orthonormal innovations, ε_t, ensure the identifying restriction on A and B:

$$A \sum A' = BB' \tag{14}$$

Both sides of the expression are symmetric, which means that $N(N+1)/2$ restrictions need to be imposed on $2N^2$ unknown elements in A and B. At least $2N^2 - N(N+1)/2$ additional identifying restrictions are needed to identify A and B. Considering the six endogenous variables that we have in our model: $M_t, X_t, P_{Gt}, P_{Ot}, P_{Qt}, Q_t$, which are the money supply, exchange rate, natural gas price, crude oil price, CPI, and GDP, the errors of the reduced form VAR are: $u_t = u_t^M + u_t^X + u_t^{P_G} + u_t^{P_O} + u_t^{P_Q} + u_t^Q$. The structural disturbances, $\varepsilon_t^M, \varepsilon_t^X, \varepsilon_t^{P_G}, \varepsilon_t^{P_O}, \varepsilon_t^{P_Q}, \varepsilon_t^Q$, are the money supply, exchange rate, natural gas price, crude oil price, CPI, and GDP shocks, respectively. This model has a total of 72 unknown elements, and a maximum number of 21 parameters can be identified in this system. Therefore, at least 51 additional identifiable restrictions are required to identify matrices A and B. The elements of the matrices that are estimated are assigned a_{rc}. All of the other values in the A and B matrices are held fixed at specific values. Since this model is over-identified, a formal likelihood ratio (LR) test is carried out in this case to test whether the identification is valid. The LR test is formulated with the null hypothesis that the identification is valid. Our system will be in the following form:

Matrix A Matrix B

$$\begin{array}{c} \\ M_t \\ X_t \\ P_{Gt} \\ P_{Ot} \\ P_{Qt} \\ Q_t \end{array}
\begin{array}{c} \begin{array}{cccccc} M_t & X_t & P_{Gt} & P_{Ot} & P_{Qt} & Q_t \end{array} \\
\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ 0 & a_{32} & 1 & 0 & 0 & 0 \\ 0 & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & 0 & a_{54} & 1 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \end{array}
\begin{bmatrix} u_t^M \\ u_t^X \\ u_t^{P_G} \\ u_t^{P_O} \\ u_t^{P_Q} \\ u_t^Q \end{bmatrix}
=
\begin{array}{c} \begin{array}{ccccc} M_t & X_t & P_{Gt} & P_{Ot} & P_{Qt} \end{array} \\
\begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & b_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{66} \end{bmatrix} \end{array}
\begin{bmatrix} \varepsilon_t^M \\ \varepsilon_t^X \\ \varepsilon_t^{P_G} \\ \varepsilon_t^{P_O} \\ \varepsilon_t^{P_Q} \\ \varepsilon_t^Q \end{bmatrix} \tag{15}$$

The first equation in this system represents the money supply as an exogenous shock in the system.[5] The second row in the system specifies exchange rate responses to money supply shocks.[6] The third row represents natural gas real price responses to exchange rate shocks. The forth equation allows crude oil prices to respond contemporaneously to exchange rate and natural gas price shocks. The fifth equation exhibits CPI responses to money supply, exchange rate, and crude oil price shocks. The last equation depicts GDP as the most endogenous variable in this system. The money supply, exchange rate, natural gas price, crude oil price, and CPI are variables that have an impact on GDP (see, inter alia, Taghizadeh-Hesary and Yoshino [2013a]; Taghizadeh-Hesary et al. [2013]). The main purpose of this paper is to measure and compare a_{54} & a_{64} which are the impacts of crude oil prices on CPI and GDP for the PRC, Japan, and the US. In order to accomplish this, we need to run this system for each of these three countries separately.

5. EMPIRICAL ANALYSIS

As mentioned earlier, the increase in oil prices that began in 2001, the sharp decline that followed the 2008 subprime mortgage crisis, and the immediate recovery that was experienced shortly after have renewed interest in the effects of oil prices on the macroeconomy. Following the financial crisis of 2007–2008, crude oil prices dropped from $133.11 in July 2008 to below $42.01 in December 2008, due to decreased global demand. Shortly after this drop, however, prices started to rise sharply again. In this paper, for this reason, we selected a period that covers the significant fluctuations mentioned above. Because of the presence of a structural break[7] in oil prices in July 2008, we divided our analysis into two subperiods, January 2000–July 2008 and August 2008–December 2013, and ran regressions for our SVAR for each of these three countries during the two subperiods before and after the sub-prime mortgage crisis, the event that caused the recent fluctuations in crude oil prices, then compared the findings.

5.1 Data Analysis

In order to reach a more realistic analysis, we express all variables in real terms. As for the oil prices, because each of these three oil importers are importing crude oil from various sources, hence for the crude oil prices, we used the simple average of three major oil price sources as in Korhonen and Ledyaeva (2010) and Taghizadeh-Hesary et al. (2013): Dubai crude oil prices in the Tokyo market, Brent crude oil prices in the London market, and WTI crude oil prices in the New York market, all in constant dollars and seasonally adjusted. Natural gas prices are in constant dollars obtained using a simple average of three major natural gas prices: US Henry hub, UK National Balancing Point (NBP) and Japanese imported LNG average prices, seasonally adjusted. The GDP of all three countries is in constant US dollars, fixed PPPs, seasonally adjusted. All of the three data series above were deflated by the US consumer price index (CPI), as most crude oil, and natural gas markets are denominated in US dollars and the

[5] For more information on exogeneity tests in structural systems with monetary applications, see Revankar and Yoshino (1990).

[6] For the impact of the money supply on the exchange rates, see Yoshino, Kaji, and Asonuma (2012).

[7] In order to find the presence of structural changes throughout the period of our survey, we used the Chow test at various points where oil prices fluctuated significantly. The results confirm a structural break in July 2008, when global oil prices dropped sharply because of lower oil demand due to the recession following the financial crisis. As a result we can determine two subperiods for our analysis: January 2000–July 2008 and August 2008–December 2013.

amount of GDP for each country was also in US dollars. For the exchange rate in the PRC's SVAR, we used the yuan REER, for Japan we used the yen REER and for the US, we used the US dollar REER (2005=100). As for the money supply, we used M2 for the PRC, Japan, and the US for each country's SVAR. From now on, whenever we refer to the price of crude oil, natural gas, and GDP, unless otherwise stated, we refer to their real values. Sources of data are International Energy Agency (IEA) (2013), International Financial Statistics (IFS) 2013, the Energy Data and Modeling Center (EDMC) database of the Institute of Energy Economics, Japan (IEEJ), Monthly Energy Review of the US Department of Energy (DOE), and the Bank of Japan (BOJ) database.

In order to evaluate the stationarity of all series, we used an Augmented Dickey–Fuller (ADF) test for all series with intercept and trend. The results imply that with the exception of M2 for the US and GDP for the PRC, which were stationary at the log level, all other variables are non-stationary at log level. However, when we applied the unit root test to the first difference of log-level variables with intercept and trend, we were able to reject the null hypothesis of unit roots for each of the variables. These results suggest that the M2 for the PRC and Japan, the exchange rates of all three countries, Japanese and US GDP, crude oil prices, and natural gas price variables all contain a unit root. Once the unit root test was performed and it was discovered that the variables are non-stationary in level and stationary in first differences, they were integrated of order one. Hence they will appear in the SVAR model in the first differenced form. This means that instead of CPI, we will have CPI growth rate or the inflation rate, and instead of GDP we will have the GDP growth rate. For other variables, we will have their growth rates in our regressions.

In order to test whether the identification is valid, the LR test was run for each country's SVAR. The LR test does not reject the under-identifying restrictions at the 5& level, implying that the identification is valid.

5.2 Empirical Result

Regressions results of our SVAR model for each country are presented in Table 1.

Table 1: Empirical Results

Country	January 2000–July 2008		August 2008–December 2013	
People's Republic of China	$-a_{64}^{CN}$ = - 0.26	S.E.= 0.07**	$-a_{64}^{CN}$ = -0.27	S.E.= 0.39
	$-a_{54}^{CN}$ = 0.02	S.E.= 0.02	$-a_{54}^{CN}$ = 0.02	S.E.= 0.02
Japan	$-a_{64}^{JP}$ = 0.03	S.E.= 0.005**	$-a_{64}^{JP}$ = -0.1	S.E.= 0.02**
	$-a_{54}^{JP}$ = 0.03	S.E.= 0.007**	$-a_{54}^{JP}$ = -0.01	S.E.= 0.007
United States	$-a_{64}^{US}$ = -0.06	S.E.= 0.002**	$-a_{64}^{US}$ = -0.01	S.E.= 0.01
	$-a_{54}^{US}$ = 0.07	S.E.= 0.002**	$-a_{54}^{US}$ = 0.03	S.E.= 0.01*

S.E. = standard error.

Note: $-a_{64}^{i}(i = CN, JP, US)$ shows the impact of oil price fluctuations on GDP growth, $-a_{54}^{i}(i = CN, JP, US)$ shows the impact of oil price fluctuations on CPI inflation. The z-statistic is obtained by $-a_{64}^{i}(i = CN, JP, US)/S.E.$ and $-a_{54}^{i}(i = CN, JP, US)/S.E$. To get an interpretation of the contemporaneous coefficients, the sign of the A matrix is reversed; this follows from Eq. 12. * indicates significance at the 5% level, ** indicates significance at the 1% level.

The signs, sizes, and significances of the contemporaneous impacts of crude oil price movements on GDP growth rates and on CPI inflation rates deserve discussion because they have important policy and theoretical implications.

Our empirical results show that oil price fluctuations had an impact on the macroeconomic variables of these three economies, which is in accordance with the theoretical part of this paper that shows oil prices have an impact on GDP (Eq. 8) and also on general price determinations (Eq. 9). However the size and magnitude of this impact varies for each country and for different time periods. Below we interpret the sign, size, and magnitude of the contemporaneous impacts of crude oil price movements on GDP growth rates and on CPI inflation rates of these three countries.

The PRC's elasticity of GDP growth rate and inflation rate to oil price movements did not change after the 2008 financial crisis. Before the crisis, the elasticities of the country's GDP growth rate and inflation rate to crude oil price changes were -0.26 (significant) and 0.02 (non-significant), respectively, and after the crisis they were -0.27(non-significant) and 0.02 (non-significant). The main cause for this is the appreciation of the yuan. Slightly after the sub-prime mortgage crisis, oil prices started to increase sharply. This happened because of a mild recovery in the global economy and huge quantitative easing (QE) policies by the US and other countries' monetary authorities (Yoshino and Taghizadeh-Hesary, 2014a). At the same time, the yuan appreciated compared to other currencies, which means that the price of crude oil in the PRC's domestic market did not fluctuate much. The result was that both before and after the crisis, the impact of crude oil prices on the PRC's economy (GDP and inflation) was almost constant.

There are several earlier studies on the impact of oil shocks on the PRC's economy that match our results (Zaouali 2007; Tang, Wu, and Zhang 2010; Du, Yanan, and Wei 2010). The PRC's oil consumption doubled over the past decade because of the country's high economic growth, which required large amounts of energy. In addition, the PRC is the second largest consumer of oil in the world behind the US. It has high energy intensity, and the energy consumption per $1,000 GDP in 2007 was 0.57 tons of oil equivalent, higher than that of Germany (0.09), Japan (0.12), and the US (0.17).

Japan's elasticity of GDP growth rate to oil price fluctuations became negative after the 2008 financial crisis, at –0.1 (significant). The reason for this is that in the wake of the Fukushima nuclear incident in March 2011, oil remains the largest source of primary energy in Japan. The disaster made the country fully dependent on imports of fossil products, especially crude oil. Japan spent $250 billion on total fuel imports in 2012, a third of the country's total import charge. Before the crisis, in the first subperiod, the elasticity of the Japanese GDP growth rate to crude oil price movements was positive, at 0.03 (significant). Worldwide increases in oil prices have had a positive effect on Japan's GDP. These findings are also in accordance with those of Jiménez-Rodríguez and Sánchez (2004), Blanchard and Galí (2007), Kilian (2008b), and Taghizadeh-Hesary et al. (2013), who all conclude that Japan has fared relatively well in the face of recent exogenous oil price shocks. However the findings by Korhonen and Ledyaeva (2010) for Japan are the reverse, as they observed negative impacts of oil shocks on GDP. This positive elasticity exists due to several reasons, such as increased energy efficiency, accumulating huge strategic reserves of crude oil, declining crude oil demand stemming from structural factors like fuel substitution (the use of nuclear electric power and natural gas), and population decline. Another reason is that in first subperiod, although crude oil prices saw huge increases, because of appreciation of the yen, resulting from accumulated foreign reserves in the country, energy prices in the domestic market did not increase much.

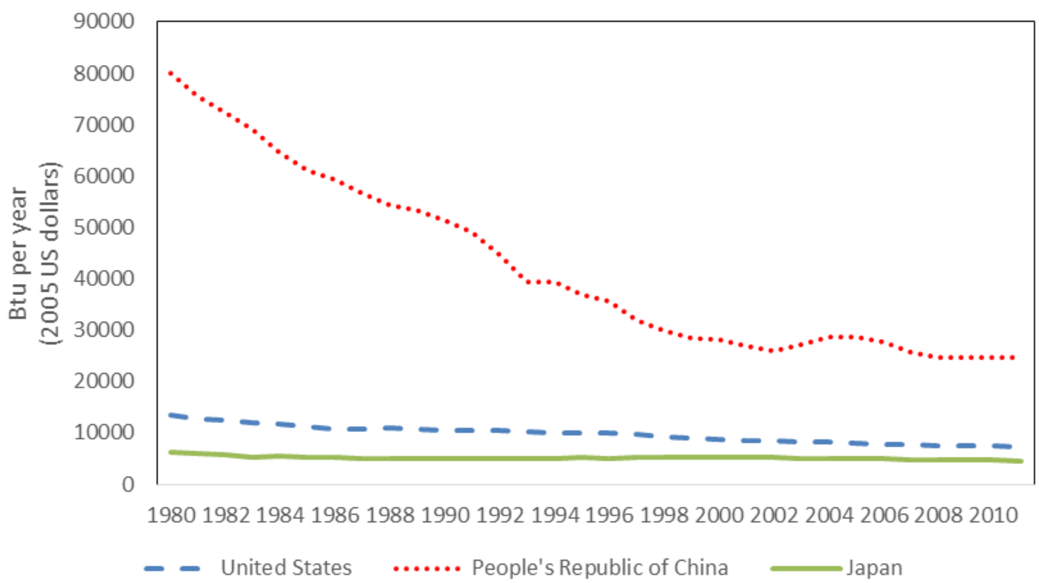
As for the elasticity of CPI inflation to crude oil price growth rates, in the first subperiod the value was 0.03 (significant), but became negative after the crisis (–0.01, non-significant). The reason for this negative impact on prices is that in Japan, aggregate supply (AS) is almost constant. Higher energy prices mainly affect the demand side of the economy. This is clearly evident in the second subperiod, shortly following the uncertain situation that occurred in the country after the Fukushima nuclear disaster. This uncertainty caused domestic consumption to shrink, resulting in price deflation.

Our empirical results show that the US economy in both periods was affected by oil prices, which is in line with several papers (Hamilton 1983, 2005; Blanchard and Gali 2007; Kilian 2008b). The absolute value of the US elasticity of GDP growth rate to oil price growth rate was reduced following the 2008 financial crisis because of lower aggregate demand in the country, caused by recession. Moreover, the impact of higher oil prices on inflation decreased in the second period because of lower aggregate demand.

The impact of oil price fluctuations on US and Japanese GDP is much milder than for the PRC. However, the PRC's CPI sees smoother rates of inflation in oil shocks compared to the US and Japan because of the higher growth rate in the PRC's economy, which shifts the AS curve forward and avoids higher prices in oil shocks. In Japan's case, the AS curve has been almost constant recently, and in the US is seeing only a small forward shift.

Figure 8 compares energy intensities in the PRC, Japan, and the US and is evidence for our finding that the PRC's GDP is more responsive to oil price fluctuations GDP for the US and Japan. Energy intensity measures the amount of energy (total primary energy consumption) a country needs to generate a unit of GDP.

Figure 8: Energy Intensity, 1980–2011



Btu = British thermal units.

Note: Total primary energy consumption per US dollar of GDP (Btu per year, 2005 US dollars [market exchange rates]). Source: US Energy Information Administration (EIA), Independent Statistics & Analysis, International Energy Statistics http://www.eia.gov/beta/international/ (retrieved Sep 21, 2015).

As is clear, although for the case of the PRC energy intensity has decreased over the last 3 decades, several reasons explain this decline: faster growth of GDP than energy demand, the services sector having a growing share of the economy, and energy efficiency programs. However, while the PRC's energy intensity decreased significantly, it is still much higher than the US and Japan's. There are several reasons behind this large gap that can be summarized in energy conservation.[8]

[8] Energy conservation means decreasing the quantity of energy used without any change in output.

6. CONCLUSIONS

In this paper, we analyzed the impact of oil price fluctuations on two macro variables of two developed countries and one emerging country. The purpose is to compare the response of countries in these two groups to oil price fluctuations. For our analysis, we selected a period that includes the most recent financial crisis: the subprime mortgage crisis of 2007–2008. This means that we simultaneously compared the impacts in the period January 2000–July 2008 with the period following the crisis, August 2008–December 2013.

Our results show that the impacts of oil price fluctuations on GDP growth rates in developed oil importers (US and Japan) are much milder than for an emerging economy's (PRC). The reasons for the difference between the impacts on these two groups are: high fuel substitution (higher use of nuclear electric power, gas, and renewables), a declining population (for the case of Japan), the shale gas revolution (for the US), greater strategic crude oil stocks and government-mandated energy efficiency targets in the two developed economies compared with the emerging economy, which make them more resistant to oil shocks. On the other hand, the impact of higher crude oil prices on the PRC's CPI inflation is milder than in the two advanced economies. The reason for this is that a higher economic growth rate in the PRC results in a larger forward shift of aggregate supply, which avoids large increases in price levels after oil price shocks.

By comparing the results of these two subperiods, we conclude that in the second subperiod the impact of oil price fluctuations on the US GDP growth rate and inflation rate was milder than in the first subperiod, because of lower crude oil and aggregate demand resulting from a recession in the economy. For Japan, the second subperiod coincides with the Fukushima nuclear disaster that followed the massive earthquake and tsunami in March 2011 and raised the dependency on oil imports. Hence, the elasticity of GDP growth to oil price fluctuations rose drastically. CPI elasticity decreased, however, because of diminished consumption, which resulted from uncertainty in the nation's future after the devastating disaster. The PRC's GDP growth and inflation rate elasticities to oil price fluctuations were almost constant in both subperiods. The main reason for this is appreciation of the yuan. Slightly after the sub-prime mortgage crisis, oil prices started to increase sharply due to a mild recovery in the global economy and huge quantitative easing (QE) policies in the US and by monetary authorities in other countries. Simultaneously, the yuan appreciated compared to other currencies, which means the price of crude oil in the PRC's domestic market did not fluctuate as much. The result is that before and after the crisis, the impact of crude oil prices on the PRC's economy (GDP and inflation) was almost constant.

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